Detection of Moisture and Moisture Related Phenomena from Skylab

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The S194 radiometric antenna temperatures have been reprocessed for the three passes over Texas with corrected Skylab and ground truth data. The soil moisture distribution in the test site has been improved by making climatic water balance calculations and deriving soil moisture profiles in additional areas within the site. These data were then subjected to surface trend mapping as described previously (NASA-CR-139989). The antenna temperatures from every 7 km along the flight track were compared with average percentage of soil moisture content within a circular area of 59 km radius. Scattergrams for the three passes over the Texas site are shown in Figures 1, 2, and 3. The correlation coefficients are -0.99, -0.98 and -0.92. Figures 1, 2 and 3 are, therefore, based on S194 footprints which had about 92% overlapping. Questions could arise concerning the independence of the data points although the S194 instrument is more sensitive to areas near the center of the footprint than near the edges. Independent footprints from the S194 were also analyzed to see what effect this would have on the high correlations. There were three independent footprints for pass 5 and pass 16, and two for pass 38. These eight independent samples were plotted in Figure 4 with a resulting correlation coefficient of -0.99. Therefore, the high correlations previously reported cannot

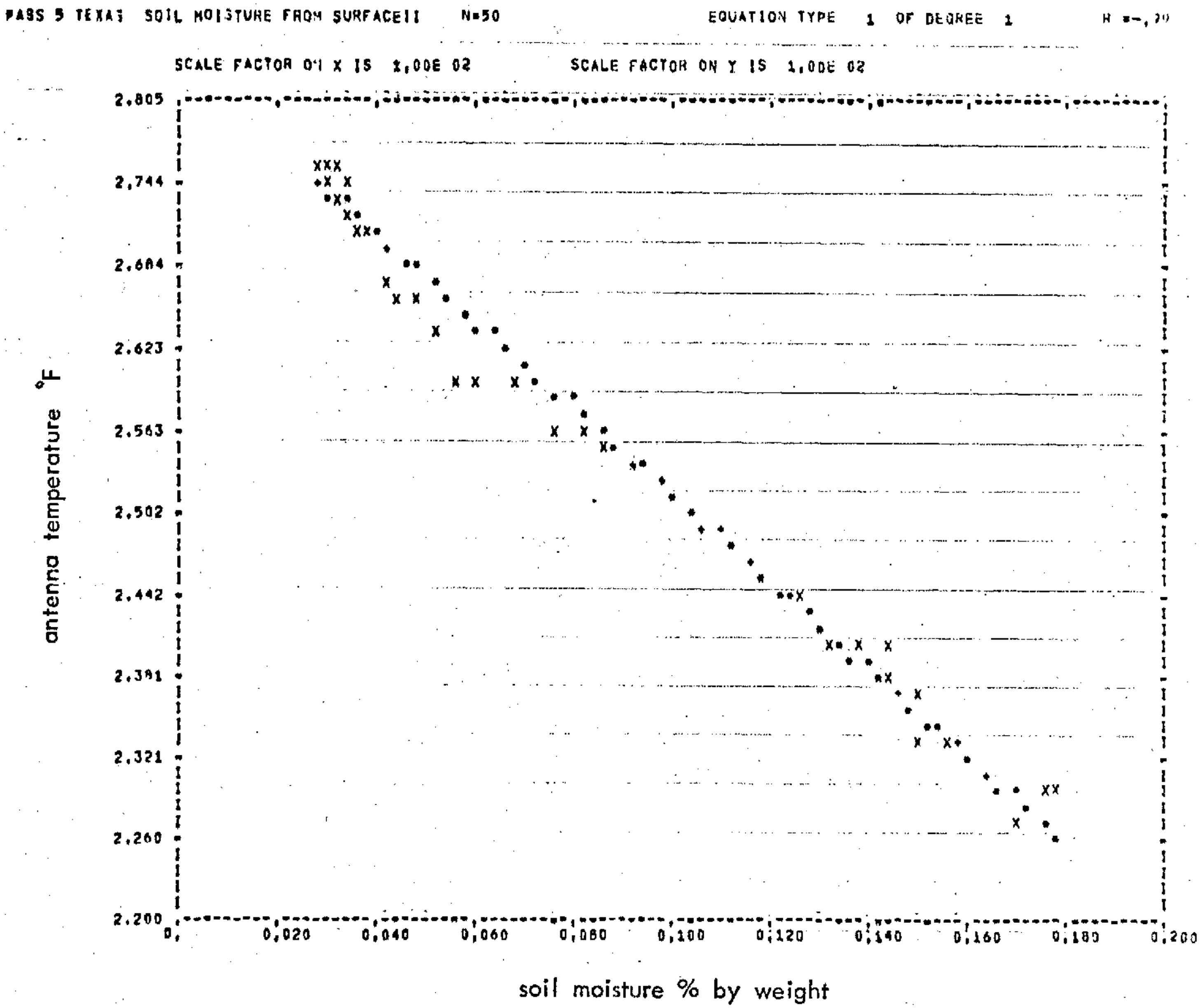

Figure 1. Correlation scattergram and the best fitted line (***) — S194 antenna temperature vs. soil moisture 0-25 mm depth, pass 5 Texas 6-5-73.

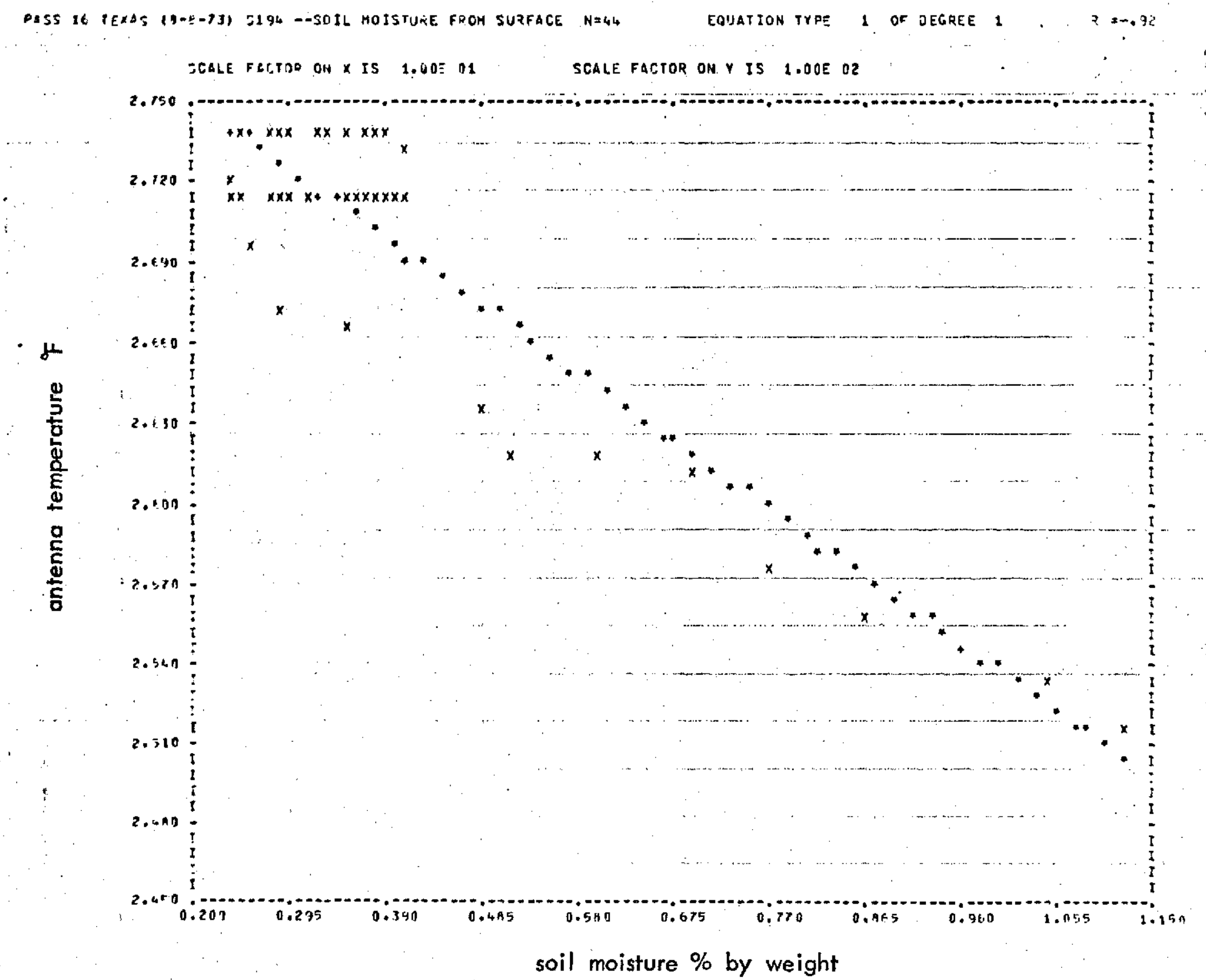

Figure 2. Correlation scattergram and the best fitted line (***)— S194 antenna temperature vs. soil moisture 0-25 mm depth, pass 16 Texas 8-8-73.

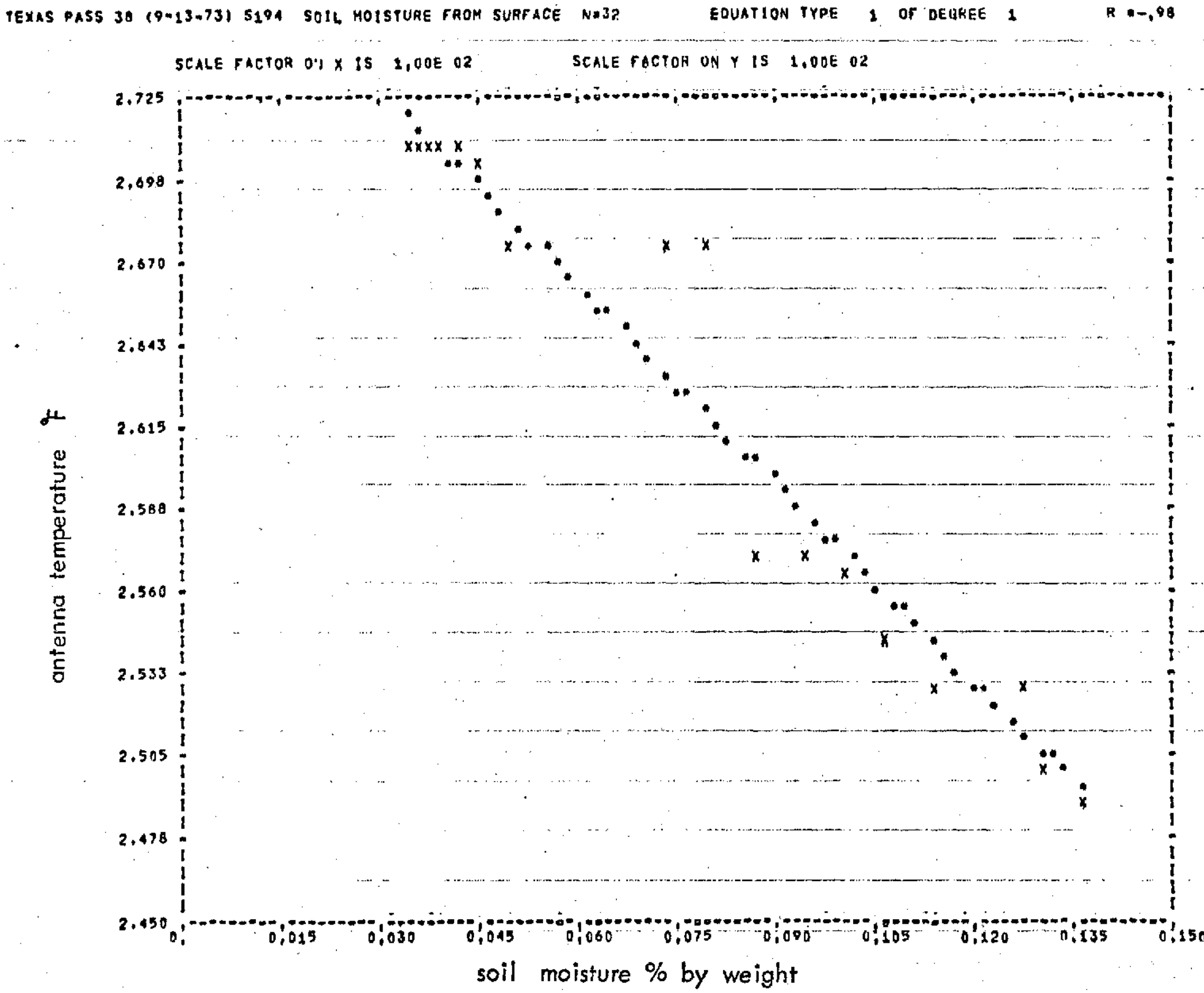

Figure 3. Correlation scattergram and the best fitted line (***) — S-194 antenna temperature vs. soil moisture 0-25 mm depth, pass 38 Texas 9-13-73.

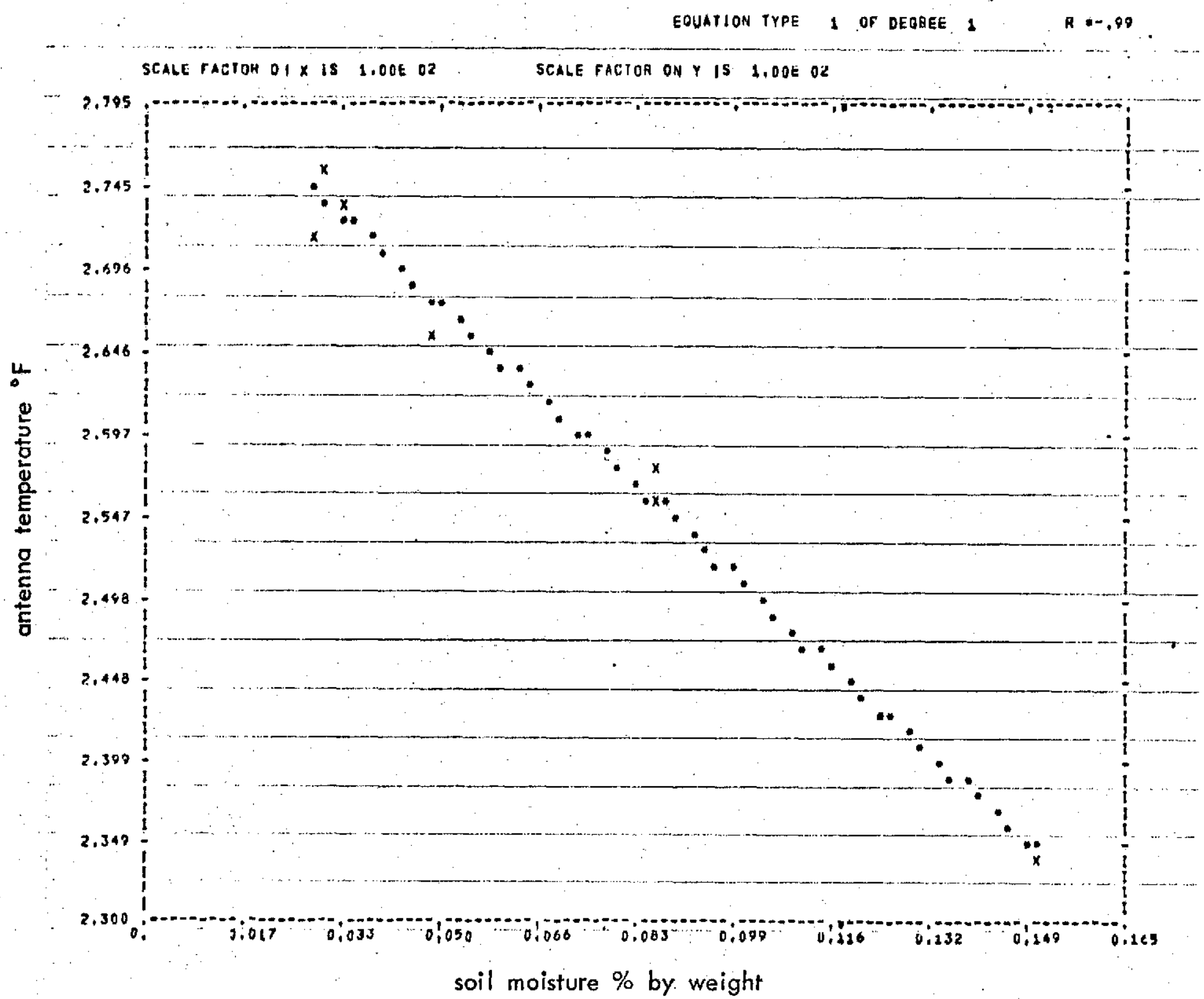

Figure 4. Correlation scatter gram and best fitted line (***) for independent footprints from Skylab S194 antenna temperatures vs. soil moisture based on three passes over Texas.

be discounted on the basis of dependent samples. The only additional reprocessing which may be beneficial involves a weighting factor for the antenna pattern of the S194 so that the center area receives more weight than outer edges. We are in the process of determining this influence but it is anticipated that it will be a minor adjustment.

The S194 radiometer can penetrate clouds and fog without serious degradation of the signal (Ulaby, et al., 1973). The effects of vegetation were found to be more significant and played decisive roles in regard to the capability of passive microwave radiometers to detect soil moisture (Newton, et al., 1973 and Lee, 1974). Although the S194 radiometer was less effected by vegetation than higher frequency radiometer, some vegetation effects were found in the S194 radiometric response during passes 5, 16 and 38 over the Texas site.

Vegetative cover modifies the soil emission through scattering, attenuation and augmentation of the original emission due to the presence of vegetation and emission from it. Sibley (1973) has made extensive theoretical studies on the effect of vegetation on radiometric data. He has developed apparent temperature models incorporating the vegetation effects for the natural terrain. He has shown that vegetation has a masking effect on the soil moisture characteristics. In Sibley's modeling of

apparent temperature of terrain as a function of soil moisture content, the thermal emission of soil and vegetation only were considered. The contributions from the atmosphere, quasi-point source and reflected sky temperature are not included in this model.

The apparent temperature measured by a downward looking microwave radiometer is given by :

$$T_a = L(T_a + T_{sc}) + T_u$$

where L is the atmospheric transmittance, T_a the apparent temperature of the target, T_{sc} is the upward scattered radiation and T_u is the upward emission by the atmosphere. For a plane surface model, T_{sc} can be expressed in terms of the downward emitted radiation T_d and the surface reflectivity, r = 1-e:

$$T_{sc} = (1-e)T_d$$

At 1.4 GHz, L and T_u at nadir were calculated to be about 0.993 and 2°K, respectively (Ulaby, et al., 1973). T_d includes downward emitted atmospheric radiation as well as galactic radiation and is estimated to be about 7°K. Attenuation by clouds in this frequency range is very small (Benoit, 1968) and hence can be neglected.

The T_a was estimated by Sibley's model for a smooth surface and uniformly vegetated surface. The total apparent temperature representing smooth, uniformly vegetated natural terrain is:

$$T_{ai} = \varepsilon_s T_g T_i e^{-2\alpha H \sec\theta} + T_c f(1 - e^{-2\alpha H \sec\theta})$$

where:

T_g = Ground temperature
ε_s = Emission of soil
T_i = Transmission coefficient for polarization i
α = Attenuation constant of the canopy
H = Canopy height
θ = Angle of observation
T_c = Canopy thermometric temperature
f = Energy transfer factor.

The accuracy in predicting the apparent temperature of the soil depends heavily on the absolute correctness of soil dielectric constant. The exact nature of the influence of the water content of soil on the complex dielectric constant has not been well defined since slightly different results have been obtained by various investigations. Hoekstra and Delany (1974) have measured the complex dielectric constant of four soils over the different frequencies (Figure 5). These dielectric constants have been used to calculate the transmission coefficient in this study.

To compute the data for this study, the canopy height was assumed to be 50 cm and the percentage of canopy volume occupied by vegetation was varied from 1% to 10%. It can be seen in Figure 6 that as the density of vegetation increases, the apparent temperature increases and becomes less sensitive to variations of soil moisture.

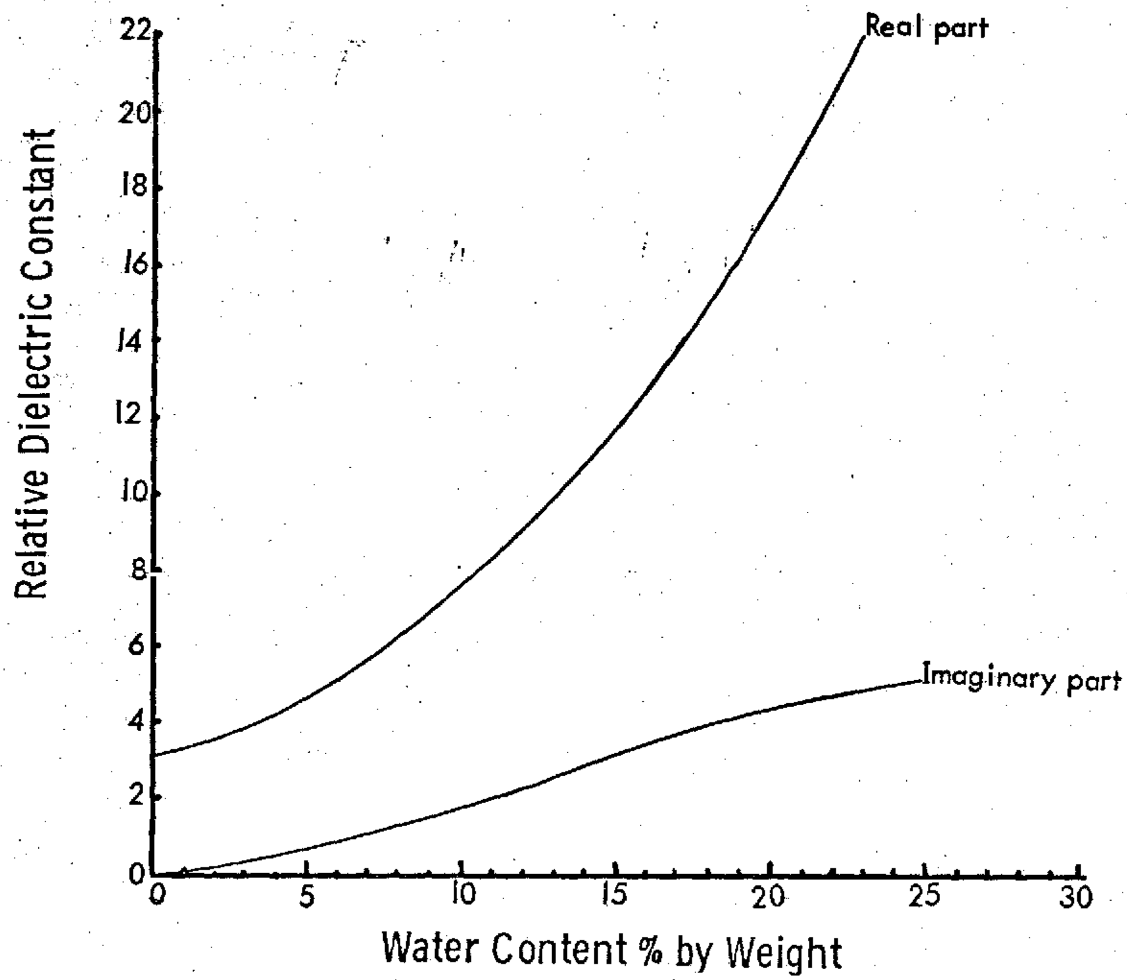

Figure 5. The complex dielectric constant of soils as a function of water content by weight at 10° C at 4 GHZ (after Hoekstra and Delany, 1974)

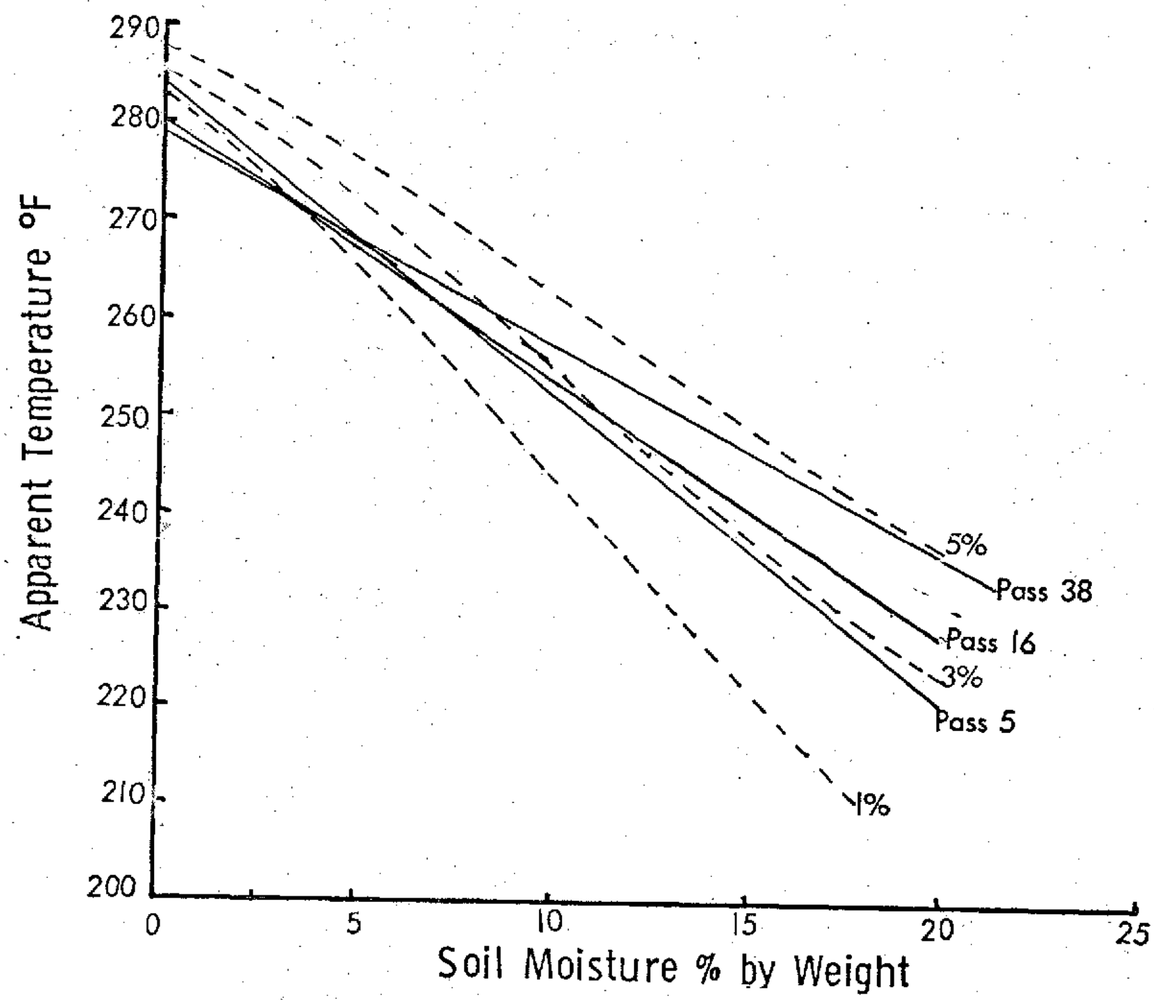

Figure 6. Apparent temperature vs. soil moisture content for theoretical predictions (dashed line) and for the best fit S194 data from 3 passes over Texas.

The S194 antenna radiometric temperatures of three passes (Figure 6) show that the vegetation density increases from pass 5 (6/5/73) through pass 38 (9/13/73). This trend corresponds with crop growth in Texas and should furnish a firmer basis for combining the Texas data with that obtained in Kansas with different vegetative cover.

SIGNIFICANT RESULTS.

The high correlations between radiometric temperature and soil moisture content are shown to remain quite high (-0.99) for independent footprints of the S194 sensor. Since an analysis based on overlapping footprints had previously been reported with a high correlation, it was necessary to verify that the correlation did not arise from dependent data.

BIBLIOGRAPHY

1. Benoit, A., 1968, "Signal Attenuation Due to Neutral Oxygen and Water Vapor, Rain and Clouds" Microwave Journal, vol. 11, #11, pp 73-80.

2. Eagleman, J.R.,and Lin, W.C., 1974. "Soil Moisture Distributions in the Test Sites" Technical Report 239-16, Atmospheric Science Laboratory, University of Kansas, NASA-CR-139989.

3. Hoekstra, P. and Delaney, A., 1974, "Dielectric Properties of Soils at UHF and Microwave Frequencies" JGR, vol 79(11), pp 1699-1708.

4. Lee, S.L., 1974, "Dual Frequency Microwave Radiometer Measurements of Soil Moisture for Bare and Vegetated Rough Surfaces", Technical Report RSC-56, Remote Sensing Center, Texas A&M University.

5. Newton, R.W., et al., 1974, "On the Feasibility of Remote Monitoring of Soil Moisture with Microwave Sensors" Presented at the Ninth International Symposium on Remote Sensing of Environment, April 15-19, 1974.

6. Sibley, T.G., 1973, "Microwave Emission and Scattering from Vegetated Terrain", Technical Report RSC-44, Remote Sensing Center, Texas A&M University.

7. Ulaby, F.T., Sobti, A., and Batlivala, P., "Atmospheric Effects on S193 Radiometer/Scatterometer Signal" CRES Technical Report 243-1, University of Kansas Center for Research, Inc., Lawrence, Kansas, June, 1973.